The Steepest Slopes on the Moon:
A Clue to Understanding Geological Processes

Why?

Slopes steeper than the angle of repose:

- Degrade with time

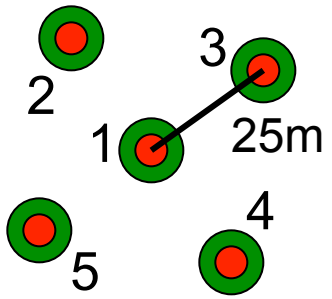
  ⇒ A clue to age

  ⇒ A clue to degradation processes

- Are formed by a limited set of processes

  ⇒ A clue to formation processes

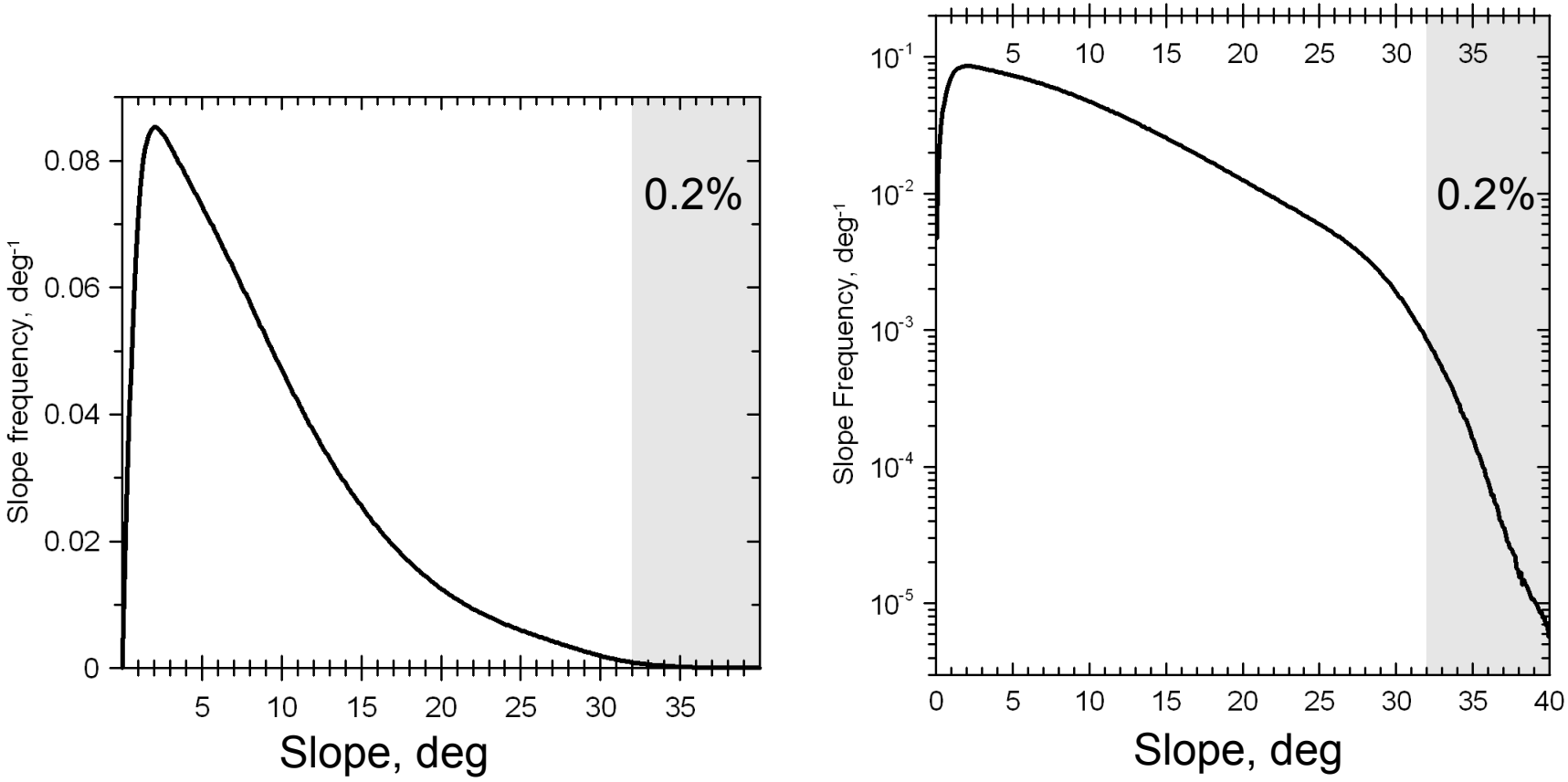
How?



- LOLA data
- Topographic gradient (aka 2D slope) at 25 m baseline
- From 3 spots within a single shot:
  - 1-2-3 or 1-3-4 or 1-4-5 or 1-5-2
  - Non-LOLA-anomaly (day time) data only; from the circular orbit only

➢ ~ 2.4 $\times 10^9$ slope measurements

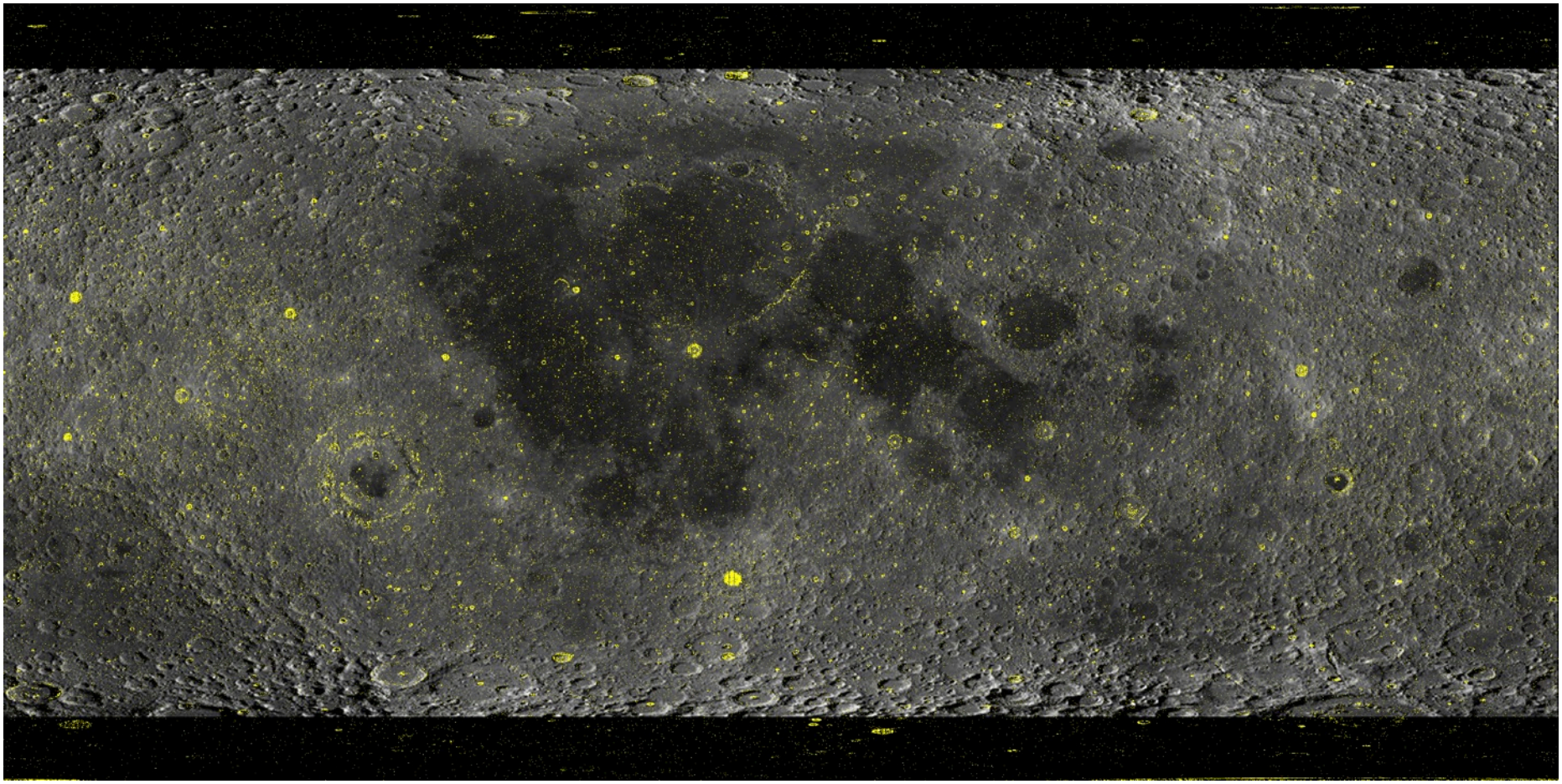
Incremental slope-frequency distribution



- Slopes >32° are extremely rare (0.2%)
- Roll-over for slopes >32°

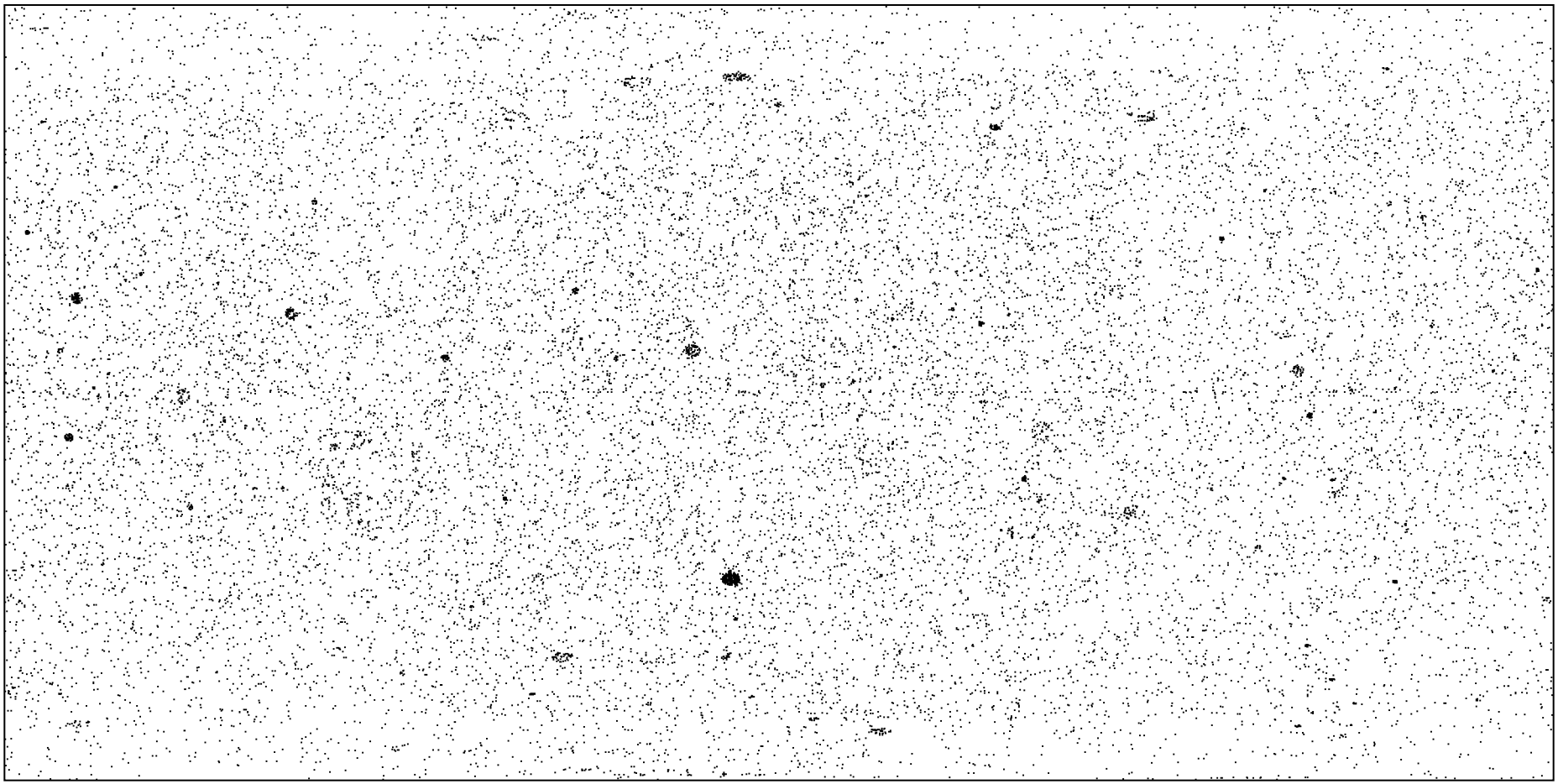
➢ Effect of the angle of repose

> 35°



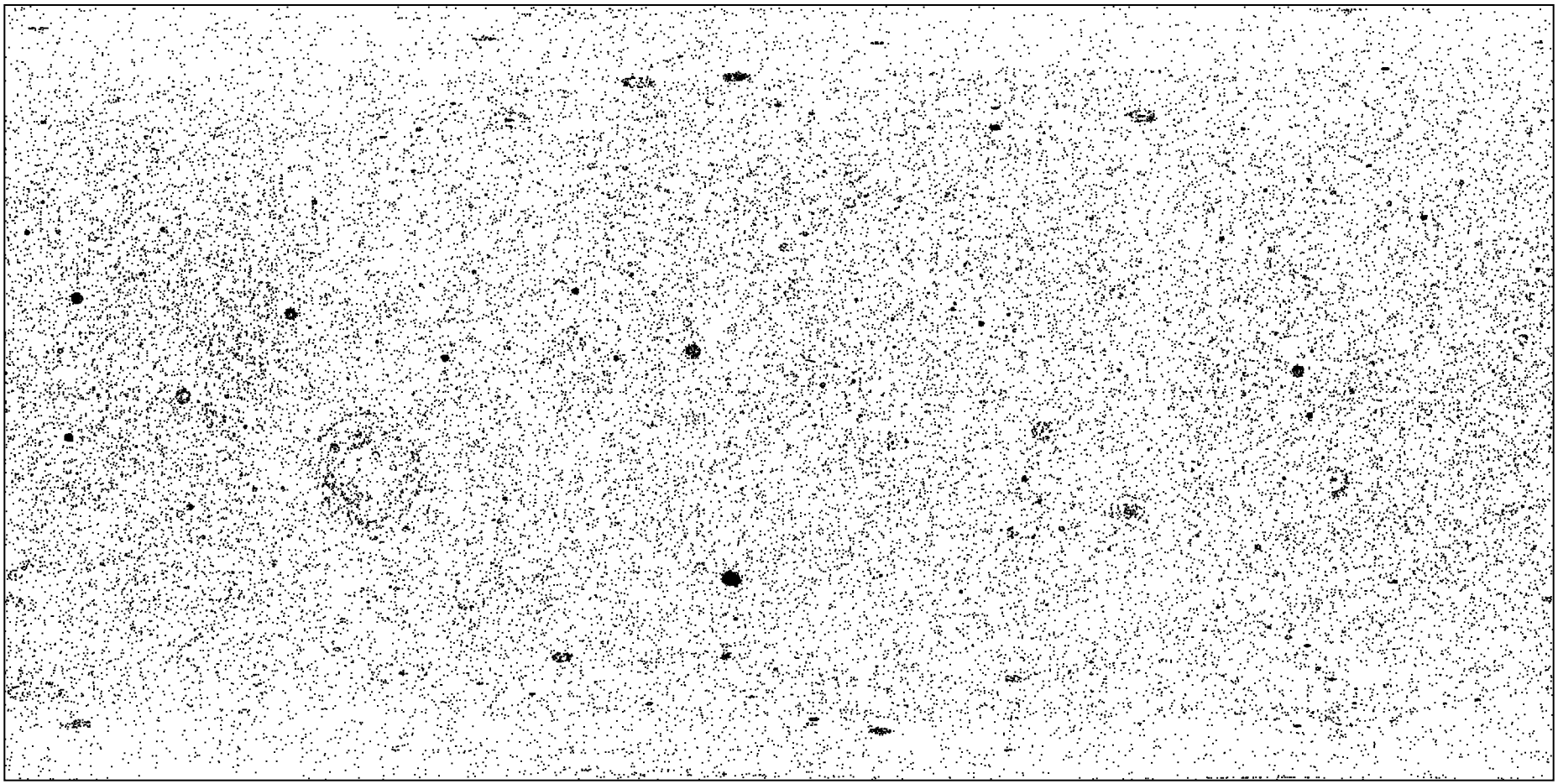
Global simple cylindrical projection
centered at the sub-Earth point

> 45°



- Large Copernican-age craters
- Some scattered dots are small fresh craters, but many of them are bad data points

> 40°



- Large Copernican- and some Eratosthenian-age craters
- Orientale basin rings
- Some scattered dots are bad data points

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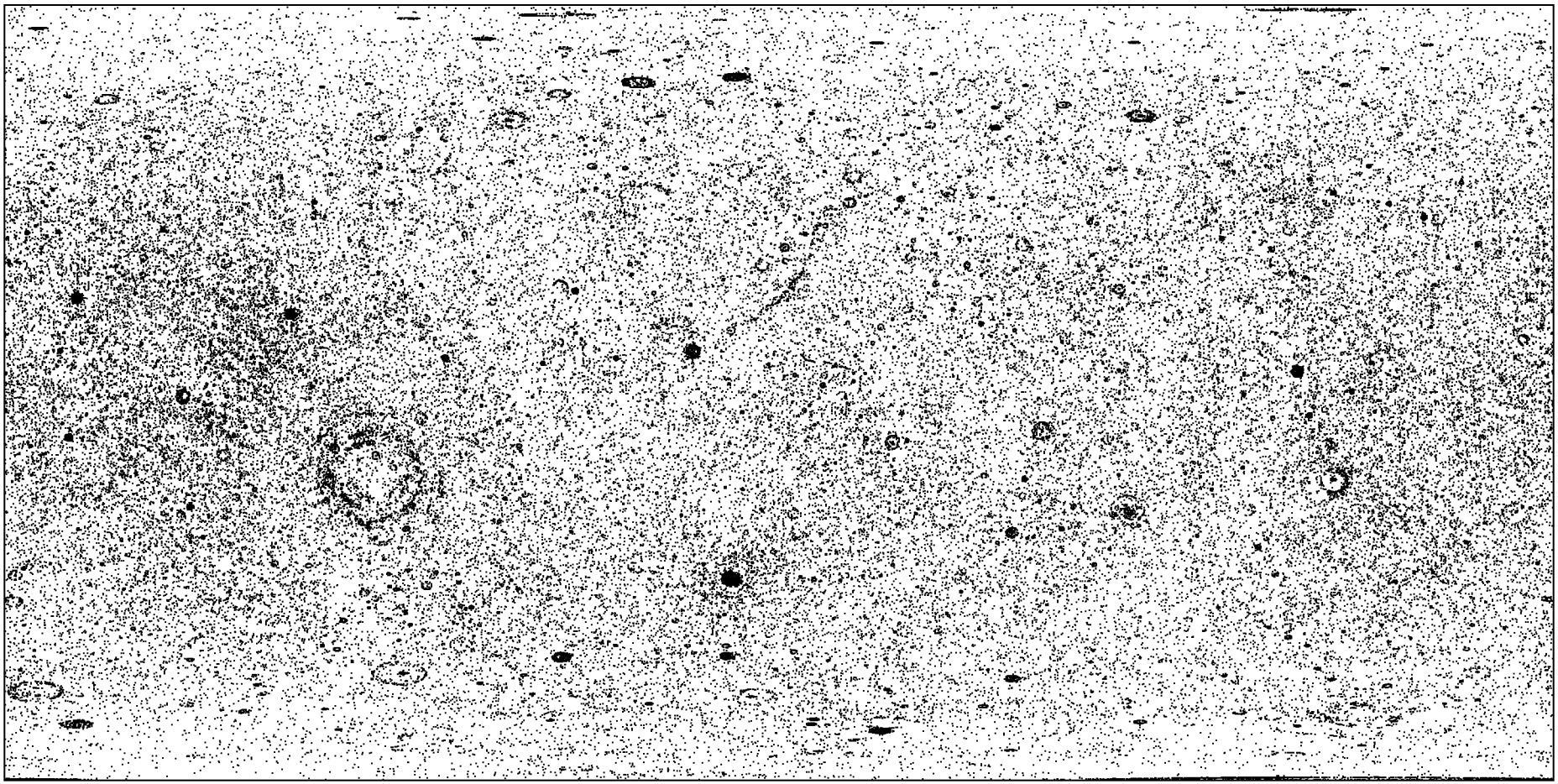
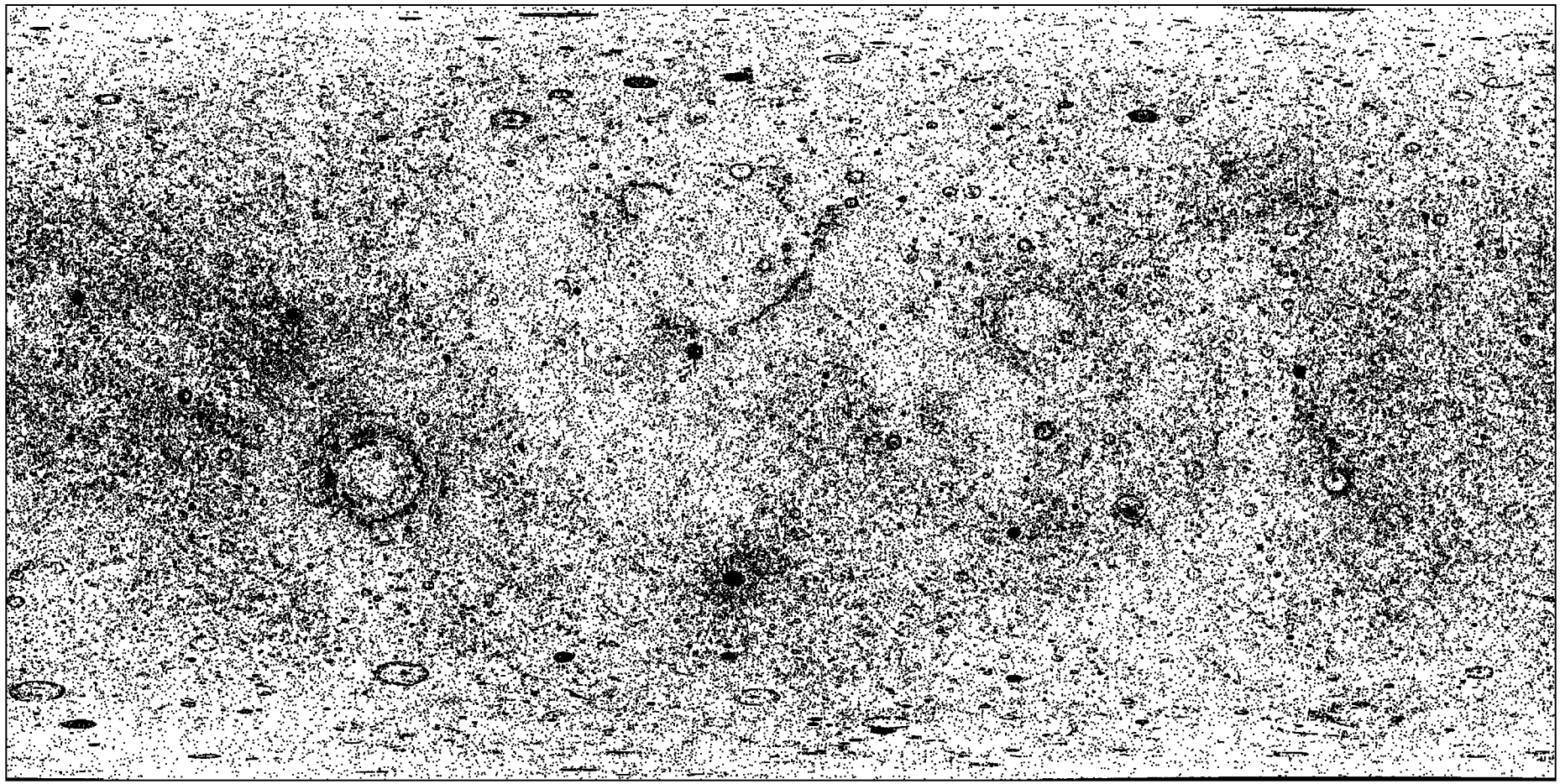


- Large Copernican- and Eratosthenian-age craters
- Orientale basin rings, Montes Apenninus
- Some Large Late-Imbrian-age craters

> 32°



- Large craters of Late Imbrian and younger age
- Orientale basin rings, Montes Apenninus, Crisium basin ejecta
- Some tectonic features.

Steep slopes on the Moon:

- Impact craters:
  - Copernican craters: **many** and steeper than 40° – 45°
  - Eratosthenian and Late Imbrian: only walls and central peaks, <45°
  - Late Imbrian + Orientale secondaries: < 40°
  - Older craters: **NO** steep slopes.
- Impact basins:
  - Orientale basin (the youngest impact basin on the Moon): **many** and steeper than 35° – 40°
  - Montes Apenninus (a part of Imbrium basin outer ring)
  - Older impact basins: **NO** steep slopes.
- Other:
  - Sinuous rills, tectonic features: < 40°

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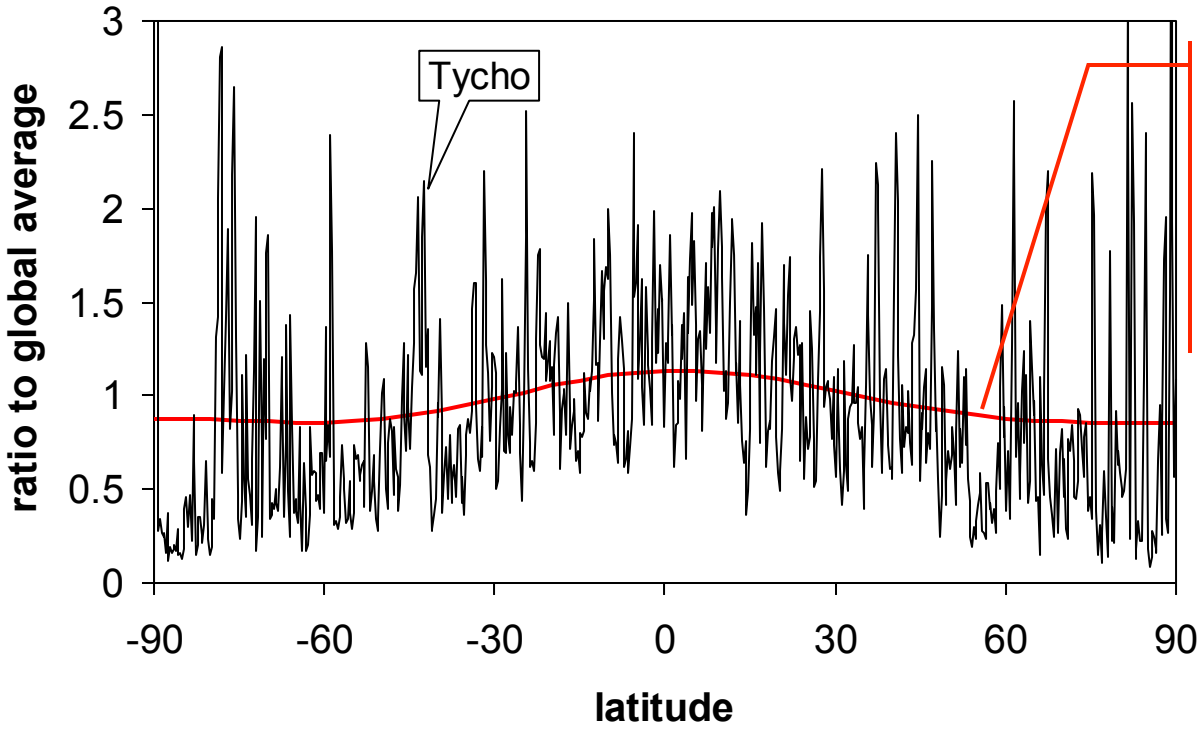
➢ Interpretation:

- ➢ Instant removal of pre-existing slopes steeper than 32° – 35° by each basin-forming impact (global seismic shaking)
- ➢ Gradual degradation of steep slopes after the latest basin

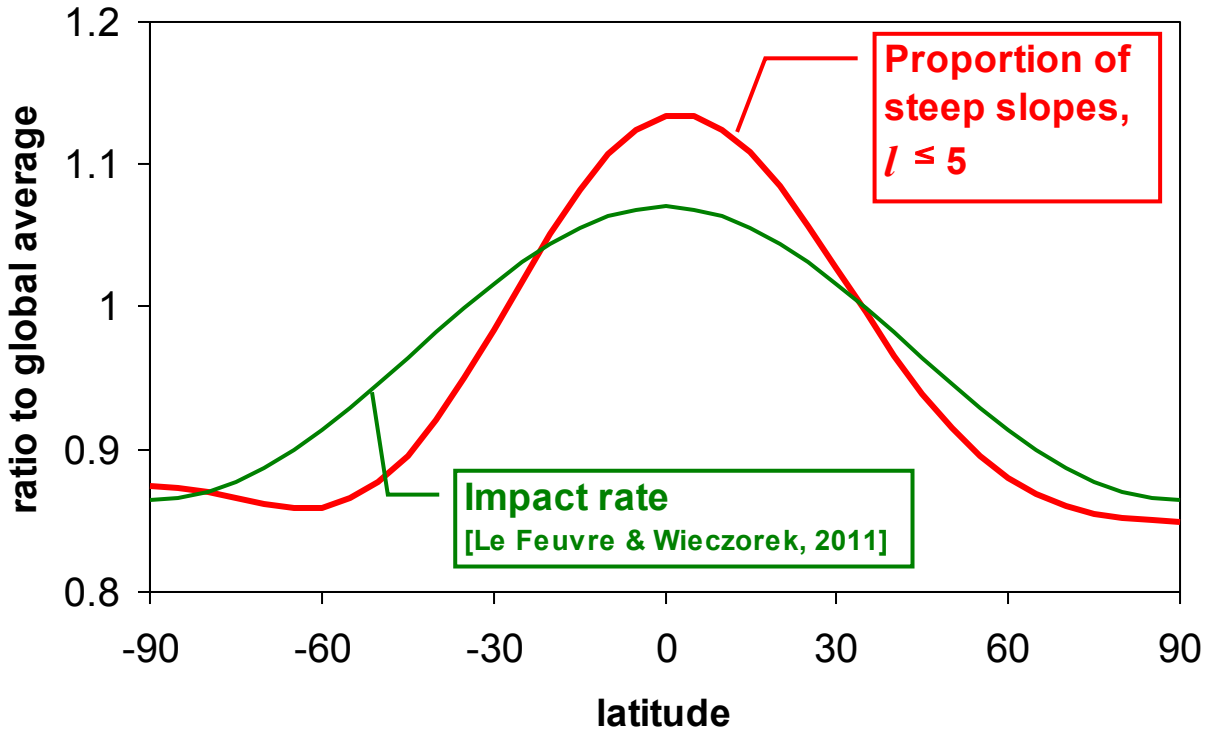
Latitudinal trend of steep slope occurrence



Proportion of steep slopes averaged over narrow latitudinal zones

- "Geological noise"
- High latitudes are noisier (⇐ smaller area of each zone)

Latitudinal trend of steep slope occurrence

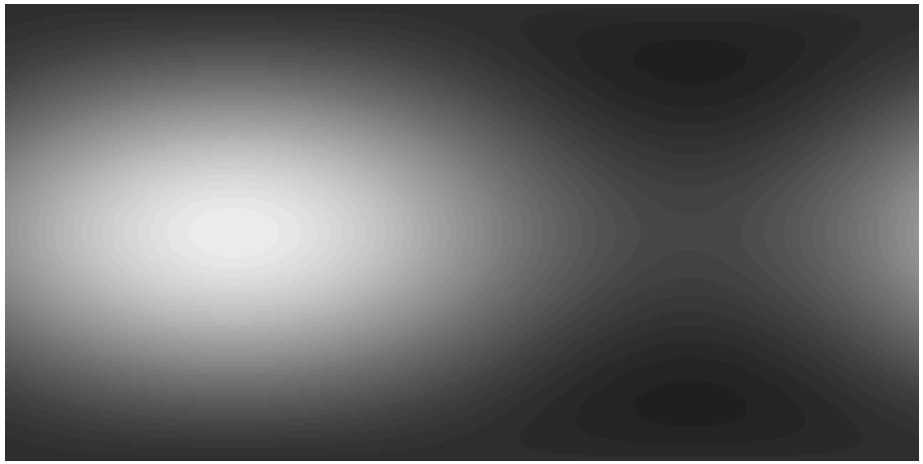


- The amplitude of the latitudinal trend is comparable to the amplitude of predicted impact cratering rate variations
- But spatial distribution is different from predicted for impact rate (next slide)
  - Maximum is shifted form the apex to the farside
  - Deep minimum associated with SPA

Topography

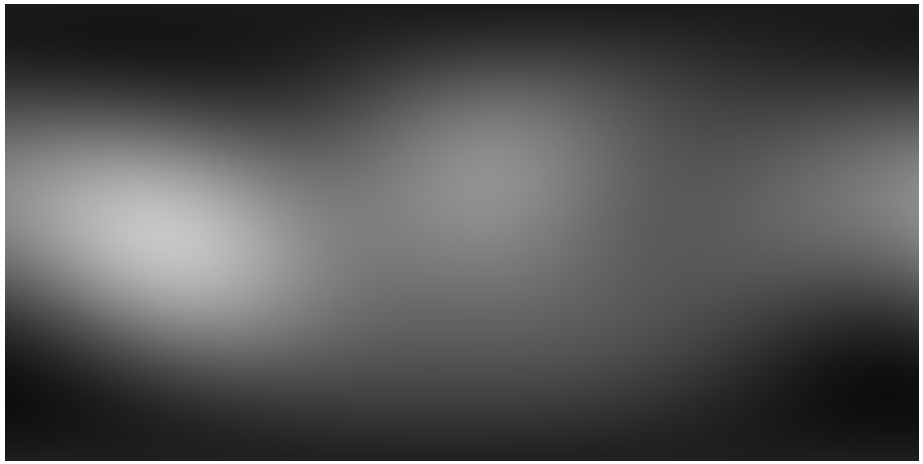
Smoothed down to spherical harmonics

$l \leq 3$



Impact rate

[Le Feuvre & Wieczorek, 2011]



Proportion of slopes

25 m baseline

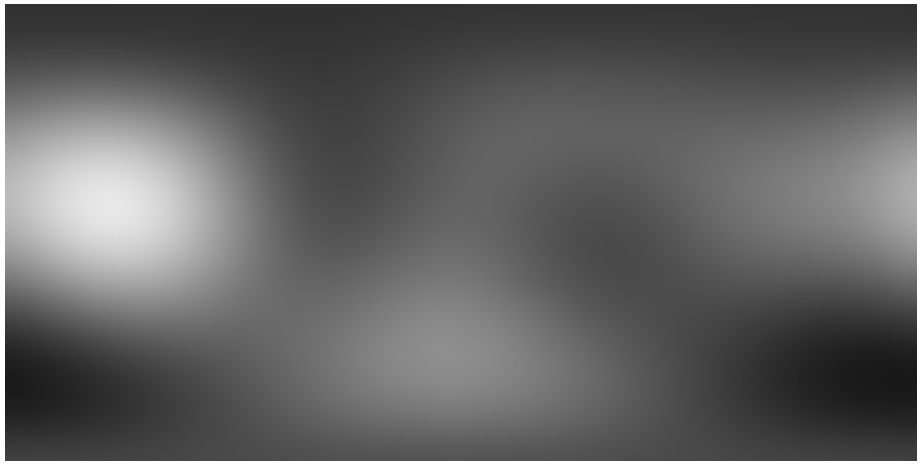
steeper than 35°

Global simple cylindrical projection centered at the sub-Earth point

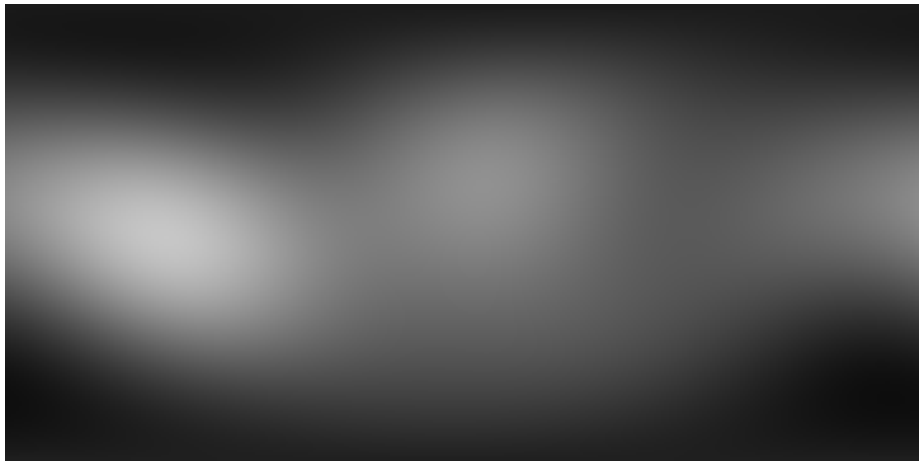
Topography

Smoothed down to spherical harmonics

$l \leq 3$



Roughness
(115 m baseline)



Proportion of slopes
25 m baseline
steeper than 35°

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Conclusions

Steep slopes:

- are rare
- are produced by impacts and tectonics
- are removed by basin-forming impacts (seismic shaking)
- are gradually degrading after the last (Orientale) impact
  - ➢ global stratigraphic marker at Early/Late Imbrian boundary
  - ➢ slopes give a rough estimate of stratigraphic age of craters
  - ➢ interesting exceptions (Montes Apenninus, Tsiolkovskiy, Taruntius)
- correlate globally with impact rate distribution, but poorly
- correlate with topography and topographic roughness
  - ➢ which is puzzling

Solving these puzzles is important for future exploration of the Moon: they are related to the surface layer, where at some points in the future we will land, rove, and work